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It is distinct honor to have been invited to speak on behalf of civil and environmental engineering on the occasion of the 150th anniversary of the College of Engineering. In this transitory society we live in, few things last 50 years, much less 150 years. Few institutions have so consistently represented high quality over such a long duration as this one, and I, for one, offer my heartiest congratulations.

There is a particularly special touch to my participation today in that the lecture I deliver is named for a civil engineering giant whom I knew and admired – Bill Richart. Bill Richart was the pioneer who created the field of geotechnical engineering, which is my own branch of civil engineering.

As a student at Georgia Tech in the 1960s, I was privileged to be among the first generation to learn from his work. And in 1970 he and two of his former students, Jack Hall and Dick Woods wrote the landmark textbook, *Vibrations of Soils and Foundations*, which I used in teaching my own courses. In addition to being a recognized leader in geotechnical engineering, he is credited with leading Michigan's Civil and Environmental Engineering department to national prominence during the 1960s. Finally I would note that Bill was the consummate professional, a man of high integrity and, in my part of the country, what we might call for those who earn it in the best sense of the word, a "gentleman." He helped nurture young people and shared his talents and the benefits of his accomplishments with others. Thus it is most fitting that this distinguished lecture bears his name.

Given the accomplishments of Bill Richart and many other great civil engineers, it would be easy for us to spend most of the time we have today talking about the past. But as we begin the 21st century I believe we have reached a critical time in the life of our profession and that we should focus on the future. It would be nice to imagine that future generations of civil and environmental engineers will be here as a part of Michigan's celebration of the 300th anniversary for its College of Engineering, but we should not be shy about asking if this overly optimistic. And to expand this a bit, while civil engineering has its unique characteristics, there are good reasons to question ourselves about where engineering as a whole will be 150 years, or even 50 years, from now.

It IS encouraging to know that civil engineers have been around a long time. They were involved in the creation of the remarkable roads and water systems of the ancient cultures epitomized by Egypt, Greece, Rome and China. But it was not until the seventeen hundreds that civil engineering was formalized as a discipline distinct from military engineering. In those days, it was possible for a single individual to have a grasp of most, if not all of the scientific knowledge that existed. So it was eminently do-able to have all of engineering contained within one discipline.

However, since then the pace of discovery has accelerated. Today, the volume of scientific and engineering knowledge is doubling every 10 years and this, along with workforce needs for new job skills, has driven the emergence of other engineering disciplines with their own distinct identities. Here at Michigan, for example, Civil and Environmental Engineering is now one of 11 departments in the College of Engineering. Civil engineering has seen the rise of new fields that seem to be better suited for capturing the imagination of our headlines-driven society. Today the buzz is about biotechnology, information technology, and nanotechnology, and traditional civil engineering, by comparison, does not sound nearly as exciting or as cutting-edge.

Along with the rapid emergence of new fields, the time-honored understanding of engineering as whole is becoming less distinct as the lines between science and engineering increasingly begin to interweave. To many it is no longer clear where science stops and engineering starts, or even where engineering stops and business begins. It is enough to make one ask if the traditional engineer as a species will even exist 50 years from now, indistinguishable among the many overlapping disciplines and interdisciplinary combinations.

Way back in my era as a student you always knew who engineers were by what they looked like: crew cut, pocket protector full of pens and a slide rule hanging from the belt. Graduates of those times sought out a great company for employment and planned on staying for the rest of their lives. Most never thought about the possible consequences of competition from foreign shores because the largest market was here in the United States. U.S. firms had no peers, and the Internet did not exist

Needless to say, times have changed. Today we live in a world where careers can shift with short notice. Rapid fire Internet linkages and growing international talent pools are loosening engineering jobs from their local moorings and moving them to nations like Russia, China and India. These nations are emerging as economic powers in part because they are doing what our nation is not doing – steadfastly investing in building world-class education systems that produce skilled technology workers like engineers.

BusinessWeek recently reported that India's schools are pumping out 260,000 engineers a year who will work for salaries much lower than in this country. China is graduating more engineers than any other country in the world – more than twice as many as the United States – and Russia has a large number of high quality engineers who are welcoming U.S. companies to open shop there.

In stark contrast on the home front, the number of American students earning degrees in civil engineering is declining. According to the National Science Foundation, the number of civil engineering degrees awarded in the United States peaked in the mid-nineties, and by the year 2000, it had declined by 20 percent at all three degree levels. But let us be completely informed. Numbers of degrees granted to engineers of most all stripes have largely declined since the early 1980's. At the graduate level the U.S. has been fortunate for many years to attract outstanding foreign talent to fill the seats of our graduate classes. But this trend is now headed down, and those international students who are still here are much more likely to return home because there are good jobs waiting for them.

So, on the surface there are good reasons to question if U.S. based civil engineering, and some of its sister traditional disciplines, are on a downward slide. If so, we are looking at a glass that is half-empty. But, being an optimist by nature, and a true believer in the unique value that U.S.-born engineering brings to play, I believe the glass is actually half full. I even go so far as to believe we have an opportunity to help build a strong future for a long while, IF we are willing to prepare for it. This is the message of an initiative being supported by the National Academy of Engineering and its president Bill Wulf, called the Engineer of 2020. I am fortunate to chair this initiative on behalf of the NAE Committee on Engineering Education, which is chaired by your own Dean of the College of Engineering, Steve Director. I will return to this later after we have laid some groundwork, beginning with a consideration of the some of the types of challenges we are facing as a society with a special emphasis on those related to civil and environmental engineering. I will follow this by talking about some of the solutions we need to develop if we are to successfully meet the challenges, and conclude with a discussion of how we might get there.

In our fascination with new technology in computing, consumer electronics, communications, and biotechnology, our society has developed a blind spot when it comes to the basics we need for our very life and breath. But old problems do not fade away when we ignore them, and we have. Let's begin by looking at the challenges society faces that should call on the expertise of civil and environmental engineers to address.

By the calculations of the United Nations, the world population crossed the 6 billion mark in late 1999. It took all of world history up until the early part of the 1800s to reach the 1 billion mark. The second billion took nearly a century. The most recent billion was accomplished in about 12 years. Fortunately, world population growth has begun to slow. The next billion is projected to take 14 years instead of 12, and sometime during the latter part of this century, the UN hopes world population will peak at 10 billion. But by then huge population increases will have occurred, often in regions least prepared to accommodate them.

The world needs to find a way to accommodate an additional 4 billion people during the next 50 years, even as we find ourselves in a veritable pothole for not having addressed the needs for our existing population. The 2003 report card of the American Society of Civil Engineers gave our nation's present physical infrastructure an overall grade of D+ and estimated that $1.6 trillion would be needed to restore it to health.

One third of our roads are in poor or mediocre condition. Airport capacity has increased by only 1 percent during the past decade, while air traffic has increased by 37 percent, causing dramatic growth in what the aviation industry calls "runway incidents," which is to say near-misses. New air traffic control technologies are being developed, but it is hard to install them in a system that can never shut down.

It is estimated that an investment of $11 billion annually is needed to bring the nation's water systems into compliance with federal water regulations. And when it comes to our sewer systems, some of which are 100 years old, the money we have been investing to upgrade them is falling short by $12 billion a year.

The process of renewing and expanding this essential infrastructure has been further complicated by the escalation of terrorism around the world, which is especially threatening to the structures that civil engineers create – water supply infrastructure, bridges, highways, large buildings, and power grids. New approaches are needed to accommodate this threat, which is likely to stay with the human race for many generations.

The inevitability of our nation's and the world's population growth and increases in urbanization will also place even stronger pressures on our fragile environment. It is estimated that ten years from now the majority of the world's population will live in urban areas for the first time in world history. Within the next two decades, global per capita forest area is projected to fall to one-third of its 1990 value, global warming will bring new threats to coastal lands and our ecosystems, and virtually every nation in the world will face some type of fresh water supply problem. We also seem increasingly

inclined to tempt fate. The past several decades have seen a global population migration to marginal land that is at risk for natural hazards from hurricanes to mudslides to earthquakes.

Taken together, the effects of population growth, increasing transportation congestion, decaying infrastructure, environmental deterioration, and need for national security represent forces of reckoning that are unavoidable. It is beginning to sound like something Woody Allen said in the movie *Side Effects*: "More than any other time in history, mankind faces a crossroads. One path leads to despair and utter hopelessness, the other to total extinction. Let us pray we have the wisdom to choose correctly."

Like Woody Allen, I believe we stand at a crossroads. But fortunately, the outcomes that Woody Allen mentions are not the only options. Civil and environmental engineers, if they are equipped with the right knowledge and tools, can offer more positive alternatives. And doing so in the face of such major needs, will help create new and exciting business opportunities for our future engineering graduates.

However, what we will make of this will depend on how open we are to developing and adopting new technologies and strategies. Why is this important? First, the expectations of the world for engineers are higher than in the past, and if we offer the same old solutions decision makers will go elsewhere for better answers. Second, we now live in a world where foreign competition will offer a cheaper alternative to anything we can do. Our solutions must be more innovative and cost effective to win the competitive circumstances we are in today. U.S. engineering stands to be marginalized if we are passive about our future.

The good news is that if we act, we have the opportunity to provide an exciting new face for engineering and to attract our share of the talent pool we need for the future. To do this our strategies need to be re-focused to take advantage of not only the best aspects of our traditional strengths but also those that will come from emerging new interdisciplinary research, new management paradigms, and even the globalization of the economy.

As a start, we must look to the exciting possibilities of new technology to energize our initiatives, and in civil engineering new technologies are more likely to come from outside our field than within. The arithmetic is simple. Research and development monies are in short supply in our field, but they are pouring into other areas like biotechnology, information technology, and nanotechnology. Our response must be to work hard to draw on fields that are advancing faster than our own. Given the circumstances, technology transfer will be the mother lode for our future. We have to

seek and adopt new technologies from other fields, and ask ourselves if our curricula are structured to encourage undergraduate and graduate students seek out new knowledge sources or simply rehash the old.

Biotechnology, for example, can open doors of opportunity for environmental engineers. At Georgia Tech we were pleased that one of *Discover Magazine*'s top 100 science stories for 2003 featured the work of Georgia Tech Assistant Professor of Civil and Environmental Engineering Frank Loeffler. He applied knowledge from biology to isolate a naturally occurring bacterium which can be used to destroy harmful chlorinated compounds in polluted environments, leaving behind environmentally benign end products. Loeffler's work offers a solution to the persistent problem of cleaning up soil and groundwater contamination by chemicals. Biotechnology also raises the possibility of treating wastewater at the point of generation, which would significantly reduce the need for large-scale sewer infrastructure.

We also are on the cusp of a new generation of high performance computing and high capacity networks. While we have been taking advantage of computing technology since the 1960s, the new wave represents a quantum leap in capacity. DOE's Oak Ridge National Laboratory is now installing a computer with a 100 teraflop capacity, and with the help of NSF, my university along with a small group of other research universities is building out a national high capacity network to allow researchers to access it. This machine opens the possibility of predicting wind loads on a local geographical scale, creating new combustion techniques to optimize sound and pollution controls, automating construction processes in real time, and modeling the behavior of buildings and structures more comprehensively than ever before.

New technology from the nanospace, is expected to have far reaching and profound effects. President Bush recently signed the authorization bill for the National Nanotechnology Initiative for a $3.8 billion R&D investment over the next four years. Developments that are predicted include new materials with remarkable performance capabilities, miniature bio-engines, powerful small-scale energy devices, and even quantum computers. It is expected that sensors as small as a dust mote, in clusters know as "smart dust," will help create buildings that can be tuned to the needs of people who occupy them, help control the effects of earthquakes and wind, reduce waste, and protect occupants in the event of fires or chemical and biological attacks.

Nanotechnology will also offer new materials that will enable us to make bridges lighter, longer, and stronger, and is creating smart materials that can adjust their properties to loading patterns and external conditions. The list of possibilities for

nanotechnology extends across a broad segment of the tools civil and environmental engineers and others will use to address future problems.

Beyond new exotic technologies, civil engineers need to make the best use of next generation management strategies to improve our productivity, something especially important in the face of cheaper global competition. In recent years we have seen growing use of techniques that utilize teaming, partnering, and entrepreneurial skills, and the Internet is beginning to profoundly influence business practices in civil engineering.

Productivity is being improved using the Internet to coordinate communications, order materials on-line, share design updates, and even hold project meetings in chat rooms. The Internet is also facilitating the use of highly integrated virtual teams around the globe in a way that is changing the traditional U.S. engineering enterprise. At Bechtel, for example, an engineer in the United States who is finishing work for the day on the design of a power plant, sends his work over the Internet to a colleague in New Delhi, India, who is just arriving at the office to begin the workday and who picks up where the American engineer left off. Some see this as a trend that will lead to a reduction in U.S. engineering jobs, while others feel it offers U.S. companies the opportunity to more readily compete for global projects. Because this trend will happen regardless of our opinion about it, we need to insure that we develop the optimal advantages for both large and small engineering firms in the U.S. We need to understand that there are niches in the global economy where our engineering services are highly desired and, as a result, will open business opportunities for us.

In the construction industry, the design-build approach is having a major impact on the way we do business, particularly in building construction. Properly done, it brings all the requisite stakeholders together around a consensus vision for projects and coordinates their efforts in a streamlined, cost-effective fashion. On my campus we have reduced the time for design and construction for major buildings by at least one year using design build. Cutting a year off of every major building and infrastructure project in our nation would have a remarkably positive effect on productivity and our ability to compete.

As we use new approaches to improve the productivity of design and construction, the growing trend to incorporate the principles of sustainable technology is not only good for our environment, it is good for business as well. Society's built environment has traditionally been viewed as something that of necessity happened at the expense of environmental preservation. However, as population has grown and natural resources have dwindled, we are coming to realize that any approach to development that is

adverse to environmental preservation and resource conservation is a dead end. Civil engineering lives at the intersection human society and the natural environment, and it is entirely appropriate that civil and environmental engineers, as well as all other engineers who work on the built environment, become known as champions of saving the environment for the future all of the world's creatures.

Sustainability mandates a different approach to design and problem solving, and if all engineering students graduate with this understanding we will change the world for the better. Hopefully, U.S. engineers will lead the way and use this as a competitive advantage. Fortunately this is a growing movement that now includes your great university and is supported by ASCE and the National Academy of Engineering. At Georgia Tech we have a fully developed curriculum for all engineering students on the principles and practices of sustainable technology, and civil engineers played a large part in its development.

On our campus we mandate the use of sustainability in the development of all of our projects. We are proud that our most recent project won a LEED Silver designation of the Green Building Council as one of the 15 or so projects in the nation that meets this high standard. I understand you have a building project here on your campus that expects to meet the LEED standard as well, and I applaud you for this.

While those of us in the developed world should rightfully be concerned about improving what we do with our advanced societies, those that will experience the strongest population growth during the next 50 years are the ones that are least developed and most politically unstable. In many cases they lack the basic infrastructure that provides the foundation for the health and gainful employment of their people. In the developing world, 1.2 billion people currently lack safe drinking water, 2.4 billion have inadequate sanitation, 2.5 billion do not have access to modern energy supplies, and 900 million live without reliable roads to provide access to markets, jobs, and health care.

The developing world offers civil engineers both here and elsewhere a unique opportunity to leapfrog older technologies and bring new technology to the fore quickly. For example, the huge power grids of the developed world are expensive to maintain and vulnerable to terrorism in developing countries. In shaping energy infrastructure for the developing world, we may be able to use new approaches such as hydrogen fuel cells to generate power with small units that are easy to replace, and have the added advantage of generating water as a by-product. If we take the lead in developing such approaches, it will lead to the creation of new business opportunities here at home.

Sustainable technology, drivers of the global economy, interdisciplinary trends, cutting edge management strategies, are some of the key concepts civil and environmental engineers, and related disciplines, need to understand and react to if we are to address the challenges we face. In my opinion, if we become adept at dealing with these complex concepts, it naturally positions engineers as leaders.

What are skills we need to be leaders? Many of them we have already embraced to some degree – creative thinking, communication skills, problem-solving skills, an ability to work on teams and a desire to serve to better the interests of our fellow humans. All of these characteristics will be needed if civil and environmental engineers are to help fill the gap in increasing the pace of bringing new technology into the public domain. To do this we will need to enhance communications with the larger public, and interact more with government officials on public policy. A daunting task, but one that is not out of our reach and one that will (a) bring excitement to our profession, (b) raise its profile with talented young people, and (c) be good for business.

As technology becomes pervasive in all areas of our lives, the link between engineering and public policy should grow. Now, by public policy I do not mean partisan politics. Public policy involves establishing the legal and regulatory framework within which society operates. Of course, public policy can be driven by partisan politics, and when that happens without the tempering influence of objective technological expertise, the results can be disastrous. Often times, civil and environmental engineers can do much public good by working to help the public and elected officials understand complex issues. This role cannot be under-estimated and this is true at the most local level as well as at the national or global level.

Global environmental conferences like the ones in Rio and Kyoto make clear the difficulty of finding political solutions to environmental problems. Political solutions invariably call for someone to give up something, and no one wants to volunteer. Sustainable approaches that use innovative technology will enable prosperity without jeopardizing the environment and will increasingly be the solution to the political stand-offs.

The challenges society faces and the remarkable opportunities they contain for civil and environmental engineers bring us full circle back to the need to rethink the way we educate engineers. It is a crucial time for this effort, given the possibility that we could see traditional engineering work go offshore or simply disappear as productivity gains allow more automation of our processes. Of course it's not as if engineering educators have been sitting on their hands. Curriculum change has been underway for the past decade as engineering schools sought to respond to a new generation of industry needs.

As useful as this has been, I believe that we have been making these good efforts without the right context. And that brings us to the Engineer of 2020 Project of the National Academy of Engineering.

The basic idea of this project is to step beyond the traditional paradigm where we engineering educators change things after-the-fact in response to an event or a development in society. For example, in my time as a student, engineering education was changed to add more science-based material following the Russian's launch of Sputnik. The Engineer of 2020 Project turns this approach on its head by (1) attempting to anticipate the future and then (2) suggesting that engineering education prepare graduates for the vision. The fundamental premise is no less than an attempt to take control of the helm of our ship of state and steer a course of our liking, rather than simply putting on life preservers and watching while our ship veers dangerous close to the shore. We may still hit the rocks, but at least it we will try to do it on our terms.

Of course, to begin an exercise by trying to predict the future is no easy task and we have had robust debates about it. To help we used what is known as "scenario-based strategic planning" which forces consideration of a range of possible alternatives. We have been hard at work on this for three years now and it has proven to be anything but simple. The first phase is essentially complete with a report coming down the final stretch, and this summer we will tackle the second phase by holding a conference of invitees who will examine the second question about how we should educate engineers today for the year 2020 and beyond.

In one way or another, all of the issues, challenges and opportunities I have introduced here, and even a few more, are going to be considered. Now I know you are probably wondering, is it remotely possible to accommodate new developments into engineering curricula that are already stuffed? The answer is only with great difficulty, and probably too slowly, if we continue to think only in terms of what goes on in a four-year curriculum, within the conventional classroom and including all that we try to teach today. But we don't have to be constrained by this mode of thinking. Leadership and communication skills can be taught outside of the classroom or during summer internships. New developments can replace old ones, or at least be offered as options to adventurous students. And, we could move to the standard of the master's as the first professional degree, adding more time to the educational process. Finally, we could place greater emphasis on a coherent approach to the use of continuing education to broaden engineers as their careers advance.

There is no question the next phase of this project is going to be interesting. If next July you hear that a big noise has gone off in Washington D.C. don't assume the obvious – it may well have been the debate coming from our meeting.

Will our efforts be successful? I don't know, but it is exciting to try this new high-risk, but high-pay off approach as opposed to sticking by one that is likely to cause us to lose valuable time by trying to respond later to a landscape for engineering that is changing before our eyes.

If we are able to will ourselves to create curricula and educational approaches for U.S. engineers that prepare for 2020 and beyond, this will be a major step forward. But it will not be enough, because engineering cannot by itself control its own destiny. We also need to engage our federal government to use its unique powers to help us address certain issues. For the past ten years we have seen federal support for engineering R&D decline, and scholarship and fellowship programs disappear that were designed to encourage U.S. students to undertake advanced study. This is critical because we cannot innovate and ultimately implement new developments without new technology from research and without the help of an educated corps of students who have had advanced engineering studies. A recent report by President Bush's Council of Advisors for Science and Technology urged the federal agencies that fund R&D to address both of these issues. Actions have been taken, but they are not yet comprehensive or compelling enough to change the course. All of us need to work to see that appropriate, informed pressure is brought to bear to see this to its rightful end.

Additionally we need to better understand and appreciate the emerging global economic models and develop strategies to insure that our U.S. engineering enterprise remains robust. Many are mobilizing to see what can be done, but no one has produced a magic bullet. One related effort from the U.S. Council on Competitiveness that I am privileged to be involved in is the National Innovation Initiative, which I co-chair with Sam Palmisano, the CEO of IBM. Our principal objective is to help understand what we need to do to enhance the innovation landscape for our nation and its technology enterprises, so we can maintain an edge in producing new ideas and businesses over emerging international competitors. We will hold a national summit in December and hope to have a report by the middle of the next year. Engineering would benefit by looking at the results to see how they apply to our profession.

Without doubt, there is much that needs to be done. The old swamp philosopher Pogo once said, "We are surrounded by insurmountable opportunities," and this may be our conundrum as well. But there is a saying that context is everything. Hopefully I have provided you with the context to appreciate how we might shape our efforts so as to

tackle our insurmountable opportunities. Hopefully you can believe like me that the glass for the future of civil and environmental engineering and related traditional engineering fields is half full not half empty. Hopefully you will work in your own spheres of influence to make a difference. It is time we took the initiative, stepped up to the plate, and played a role in shaping our own future.